

90th Indian Science Congress 2003 Session: Earth System Sciences

Scientific Visualization & Modeling for Earth Systems Science Education

S. Raj Chaudhury* and Waldo J. Rodriguez,
B.E.S.T Lab, Norfolk State University
700 Park Avenue, Norfolk, VA 23504, USA
schaudhury@nsu.edu
Phone: (+01) 757-823-2241 Fax: (+01) 757-823-9054

Keywords: Scientific Visualization, Education, Remote Sensing, NASA, GLOBE

Abstract

Providing research experiences for undergraduate students in Earth Systems Science (ESS) poses several challenges at smaller academic institutions that might lack dedicated resources for this area of study. This paper describes the development of an innovative model that involves students with majors in diverse scientific disciplines in authentic ESS research. In studying global climate change, experts typically use scientific visualization techniques applied to remote sensing data collected by satellites. In particular, many problems related to environmental phenomena can be quantitatively addressed by investigations based on datasets related to the scientific endeavours such as the Earth Radiation Budget Experiment (ERBE). Working with data products stored at NASA's Distributed Active Archive Centers, visualization software specifically designed for students and an advanced, immersive Virtual Reality (VR) environment, students engage in guided research projects during a structured 6-week summer program. Over the 5-year span, this program has afforded the opportunity for students majoring in biology, chemistry, mathematics, computer science, physics, engineering and science education to work collaboratively in teams on research projects that emphasize the use of scientific visualization in studying the environment. Recently, a hands-on component has been added through science student partnerships with schoolteachers in data collection and reporting for the GLOBE Program (GLOBal Observations to Benefit the Environment).

Introduction

The truly interdisciplinary nature of Earth System Science lends itself to the creation of research teams comprised of people with different scientific and technical backgrounds. This has been the model of most missions of the National Aeronautics and Space Administration (NASA), whether it be Earth Observing Systems (EOS) or space exploration. In the annals of Earth System Science (ESS) education, the lack of an academic major in the discipline might be seen as a barrier to the involvement of undergraduates in the overall ESS enterprise. This issue is further compounded at minority-serving institutions in the United States by the rarity of departments dedicated to Atmospheric Science, Oceanography or even the geosciences. Thus, researchers with credentials in these areas are typically appointed within disciplines such as physics, chemistry, biology, mathematics or engineering.

At Norfolk State University, a Historically Black College, we have run a six week, NASA-supported, summer undergraduate research program (REESS - Research Experience in Earth System Science") [1] that has created a model that involves students with majors in diverse scientific disciplines in authentic ESS research coupled with an extensive education program. The program is part of a wider effort at the University to enhance undergraduate education by identifying specific areas of student misconceptions regarding the content and process of science [2] as well as encouraging students to pursue graduate school through early immersion in research experiences [3,4]. A pre- and post-assessment test, which is focused on some fundamental topics in global climate change, is given to all participants as part of the evaluation of the program. Student attitudes towards the subject and the program's approach are also surveyed at the end of the research experience.

The program therefore has goals of (a) providing research training for undergraduates and (b) providing exposure to problems in Earth Systems Science and (c) looking at innovative ways, e.g. scientific visualization to exploit the presence of satellite based remote-sensing data on the earth's environment. The latter focus is mainly motivated through a strong connection between university researchers and teams at NASA's Langley Research Center Atmospheric Science division. The particular mechanism through which initial research problems were identified focused on utilization of vast amounts of data products from various remote sensing missions stored at NASA's Distributed Active Archive Center (DAAC). For the most part the archived data has been filtered, calibrated and normalized by mission specific parameters and is the product to which free access is given to the general public.

The use of scientific visualization as a tool for secondary science and college students to manipulate large data sets is a movement that has gained considerable ground in the United States over the past few years. Vast amounts of digital information about the Earth have been gathered in the last few decades. Unfortunately, for years only a small group of scientists, who had the computing capabilities, were able to visualize and interpret the data; therefore large amounts of data have not been studied in detail or ever utilized. The recent availability of sufficient computing power to the average citizen and the popularity of the Internet has prompted a flurry of interest in re-visiting old data as well as preparing for the expected massive wave of future data. Institutions of higher education need to prepare the scientists of the future to effectively operate in this overwhelmingly data-rich environment.

Summer Research Experience (REESS)

One of the principal goals of REESS is to expose a large community of undergraduate science majors to the possibilities of research careers in Earth System Science. In addition, the professional NASA research teams we collaborate with are constituted of people with different academic backgrounds. Hence student participants in REESS over the past three years have majored in biology, geology, geography, computer science, chemistry and physics. In addition community college (2 year) students were recruited. This part of the college population is often overlooked in the more established summer research programs for undergraduates (such as those organized by national laboratories or NASA installations). In building the pipeline of future minority scientists in the USA, an early research experience has been shown to be a positive catalyst. REESS has therefore no

restrictions on academic status for applying i.e., full time students from freshmen through juniors have been eligible to apply. The recruiting strategy has been successful in attracting a diverse range of applicants from a variety of institutions – from minority schools to mainstream schools, from small private liberal arts colleges to large state universities. There has been a balanced mix of commuters and out-of-towners, of males and females, and of students of various ethnicities.

The model of intensive work in the summer is important at American institutions catering primarily to minority students. Most of the undergraduates at these colleges must work in the private or industrial sector while they are pursuing their studies in order to provide financial support for themselves. Thus, they have little time during the regular academic year to pursue research opportunities. On top of that, due to gaps in their high school preparation, many science majors find themselves with heavy courseloads in order to complete the regular curriculum in close to 4 years. This further limits their time and attention for research during the academic year. Hence, summer is a time where a paid internship can facilitate an immersive research experience with few outside distractions. From our experience over the past 5 years, students can be more productive in a six-week summer period than in an entire 9-month academic year!

In the first week of REESS the students are divided into three or four person research groups. The groups are designed to have multiple academic majors represented and the project directors make initial assignments. The project mentors suggest possible research topics since the students coming into REESS rarely have much appreciation of the types of topics that are of current interest to ESS researchers. These mentors have been drawn from both within and outside the University. At the end of the first week, students make group presentations on their initial literature search/Internet search on the topics they selected. This continues each week till the final presentations on the last day of the program. These weekly oral presentations help provide focus for the group's work during the week. It also provides an opportunity for some students to become familiar with professional graphics and presentation tools.

Appropriate tools 1: WorldWatcher

While data from the NASA DAAC is freely available via the internet or CD-ROM, most of this data is not *accessible* to the non-scientist, i.e. the formats, metadata content, relevance or importance of the data for a particular task is not easily identifiable. Data is stored typically by experimental platform or by mission and not by topic of research interest. Thus many intermediary steps are necessary to bring the data stored at the DAAC into the hands of undergraduates to be usable in a six week period in some productive way. The programming tools and visualization environments used by scientists typically have too steep a learning curve to be useful in a summer program.

The software called **WorldWatcher** is a tool that was designed to bring the power of scientists' computational tools to learners [5]. It was created by adapting scientific research tools to provide the support required by students and teachers using the principles of learner-centered design and has been extensively tested with various student populations. While initially designed for high school students, the software has many necessary attributes to assist REESS students in their initial investigations. WorldWatcher displays

gridded geographic data in the form of interactive color maps that users can customize by adjusting the color scheme, magnification, and spatial resolution. In addition to data visualization, WorldWatcher supports data analysis through arithmetic operations and statistical analyses. Rapid startup of student investigation is possible because the software package not only provides graphical tools, it also includes data products derived from a variety of satellite experiments that support a wide variety of research projects. The Earth Radiation Budget Experiment (ERBE) data set is one such example that allows students to investigate global warming. Two major questions that could be answered are given below:

Research project: **Global warming investigation**

- What are the seasonal and monthly variations of global temperature distributions?
- What is the correlation between atmospheric warming and global distributions of greenhouse gases and aerosols?

Appropriate Tools 2: Virtual Reality

While WorldWatcher provides a low cost, desktop based entry into the world of scientific visualization, we have also been exploring the intuitive use of Virtual Reality (VR) techniques for the involvement of undergraduates in research. The system comprises of a Silicon Graphics Onyx2 supercomputer attached to an Immersadsk2 VR display. The user dons a pair of interactive goggles which provides an immersive, perspective, pseudo-3D view and uses a joystick to navigate the environment. Other goggles allow additional users to view the same scene that is controlled by the main user. The software package whose use we are pioneering at Norfolk State University is called vGEO [6] and has been specifically designed for the display of data sets related to the Earth. It has its roots in software for the CAVE (Cave Advanced Visual Environment) and was based on a desktop visualization package called Vis5D [7].

Two students working closely with their mentor and with staff from the software vendor company have succeeded in converting data sets from the DAAC for usage in vGEO. They have isolated data on a particular atmospheric species (ozone and water vapour) for a particular time period (1992-93) from a particular satellite instrument (Stratospheric Aerosol and Gas Measurement II). This data was then suitable for rendering in vGEO. The scientific problem addressed is given below:

Research project: **Investigate Stratospheric-Tropospheric Exchange utilizing SAGE II data**

- What are the seasonal and monthly variations of Stratospheric-Tropospheric Exchange?
- What is the vertical structure of Stratospheric-Tropospheric Exchange processes?

Ozone and water vapor 3-dimensional data was incorporated on a 3-dimensional navigable Earth sphere. Navigational capabilities of the VR system allow the user full inspection of the spatial characteristics of the data. The data can be displayed in any choice of three-dimensional perspective of the specie vs. latitude-longitude, altitude-latitude or altitude-longitude, giving the user visualization from any possible perspective. A zooming

capability allows regional studies and a tropopause flag assists for tropospheric studies. These visualizations show relationships between atmospheric chemical species, effect of spatial dynamics, and seasonal and annual trends [8].

The role of GLOBE

While the tools and research activities described above have succeeded in engaging students effectively with projects that can be addressed and completed in a six-week, albeit intensive, summer period – they are inherently computer based and provide only one dimension of the types of Earth Systems Science research activities professional engage in. The GLOBE Program (GLOBal Observations to Benefit the Environment) is an international science education project that spans 100 countries (including India) and several thousand schools worldwide. Teachers lead teams of students in making regular measurements of various phenomena related to the Earth System following strict protocols outlined by the GLOBE manual and then communicate their observations to the GLOBE database via the Internet. Norfolk State University has been a lead institution of higher education in our geographic area (Southeast Virginia of the USA) to provide teacher training workshops in the GLOBE protocols which span atmosphere, hydrology, soil and land cover (to name a few).

We have recently started to involve college students in GLOBE data collection activities since some knowledge of science is necessary to accurately complete some of the protocols. In the summer of 2002, the REESS students were trained in various GLOBE protocols and each group was assigned a particular protocol on which to systematically collect and report data. The field work was welcomed by many students as a diversion from computer intensive work that they were engaged in for most of the REESS program.

Program Summary

Since most students who have participated in our program have not committed to pursue further study in the area of Earth Systems Science and because the REESS program has some unique features not found in a typical academic curriculum, it was felt important to ascertain how students' attitudes were influenced by the program. In each year of the program, different interesting aspects of the interaction between students, mentors and research material emerged. Group dynamics, as indicated on exit surveys, varied tremendously from group to group, from year to year. Similarly, mentor-group dynamics were often cited as contributing to perceived success or failure on the part of the research groups.

It is important to note that on issues of learning Earth Systems Science content and learning the skills of visualization, as measured by our pre- and post-assessments and student surveys, REESS has been a success. Students demonstrate comprehension of several important issues related to global climate change and exhibit skills with data manipulation, visualization, interpretation and presentation that they did not possess at the onset of the program.

Conclusion

The REESS model should be considered by smaller institutions (without post-graduate programs) as a way to involve undergraduates in interdisciplinary research. Various software tools and data resources are available to assist in this research training and exposure to Earth Systems Science.

References:

- [1] Rodriguez, W. J. and S. Chaudhury, "Research Experience in Earth System Science at Norfolk State University", *Proceedings of the Eighth NASA MU-SPIN Users' Conference*, Albuquerque, NM, 1998
- [2] Golembiewski, G., S. M. Black, W. J. Rodriguez, C.E. Bonner and S. Chaudhury, "Investigating student knowledge states in Earth System Science", *American Association of Physics Teachers*, National Meeting, College Park, 1996
- [3] Chaudhury, S. and W. J. Rodriguez, "The BEST Lab – Fostering the Growth of Geoscience Education at an Historically Black University", *Abstracts of American Geophysical Union*, Spring Meeting, Boston, 2001
- [4] Chaudhury, S. and W.J. Rodriguez, "Diversifying Earth System Science Education – the Undergraduate Research Model," *Proceedings of International Geoscience And Remote Sensing Symposium 2000*, Honolulu, Hawaii, July 2000
- [5] WorldWatcher, <http://www.worldwatcher.nwu.edu/>, Northwestern University, Evanston
- [6] vGEO software is published by VRCO, <http://www.vrco.com/>
- [7] Vis5D, Space Science and Engineering Center, University of Wisconsin, Madison
- [8] Youssef, E., L. Youssef, and W. J. Rodríguez, "Scientific visualization tool for Stratospheric Aerosol and Gas Experiment data", *American Chemical Society National Meeting*, New Orleans, Louisiana, 1999